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ABSTRACT

Intended to provide a frame of reference for a symposium on automated aids to instructional design and development (ID), this paper accomplishes three tasks: (1) it outlines problems encountered in ID--e.g., complexity of curriculum planning and instruction development, quality maintenance in the ID process and products, and cost effectiveness--in order to show the need for improved procedures and automated aiding systems; (2) it describes various classes of functions the aids might serve--data-base management, instructional design decision-making, material production, personnel training--relates them to the programs discussed by the other symposium participants; and (3) it makes some conjectures about the potential of developments in intelligent computing for assisting ID. A list of references is provided. (Author/JD)

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Design Considerations in Computer-Based Instructional Development Systems[1]

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Abstract

Implementation of instruction design and development systems encounters three general problems: keeping track of and integrating the actions taken decisions, and products; inadequately specified procedures, and inadequately trained personnel; and high, visible costs. This paper provides a frame of reference for the symposium and describes various types of computer-based aids which encompass the work of the other symposium participants. Recent work using Artificial Intelligence in instruction suggests that a similar approach attempting to use an "intelligent" computer as an instructional designer might give greater insight into the design process.

Design Considerations in Computer-Based Instructional Development Systems

When one hears about computer-based systems in instruction, the first thing that comes to most people's mind seems to be the use of a computer to assist in various ways in the management of instructional transactions, that is, the delivery of instruction. Computer-based instruction has been lauded (and sometimes damned) widely in various professional and popular journals and books for twenty years or so. The popularity of this view is at once understandable and unfortunate. It is understandable because: computer scientists desire widespread utilization of computers for significant problems, researchers are interested in systematic application of learning theory in order to optimize learning, and teachers recognize some of the inefficiencies of classroom instruction. It is unfortunate from the viewpoint that it tends to put the cart before the horse. It assumes we know what we want to teach and how to go about doing so.

The adequacy of any instruction is strongly determined by the adequacy of the analysis and specification of what students are to learn, the development of accurate competency measurement, and the organization of instructional content and experiences. Inadequacies in instructional preparation yield inadequate instruction no matter how the materials are presented. It is the theme of this symposium that the process of instructional design and development (ID) is complicated, costly, and relatively inefficient. We want to call attention to the potential of

computer-based systems for assisting this process, discuss some recent developments, and the need for other aiding systems, thereby putting the horse back in its place before the cart. This attempt seems especially important because little attention is paid to instructional design and development problems by those intensively concerned with the development and the use of computer-based systems in education. For example, in a recent conference attempting to forecast how computer and communications technology would impact on educational practice in the mid-1980's, no direct mention was made of ID (Seidel & Rubin, 1977). This oversight is especially important because the use of existing computer and software technology can produce substantial increments in the effectiveness and efficiency of the ID process. Furthermore, this claim can be evaluated directly.

My discussion is intended to lay the groundwork for the rest of those in the symposium. First, problems encountered in instructional design and development will be outlined in order to show the need for improved procedures and automated aiding systems. Then, various classes of functions the aids might serve will be described and related to the programs discussed by the other symposium participants. Finally, some conjectures about the potential of developments in intelligent computing for assisting ID will be made. No attention will be given in this paper to particular computer hardware or software. Some of that will be discussed in the other papers. Many state-of-the-art information management techniques/systems could be used effectively in ID without substantial new development.

Problems in Instructional Development

A variety of trends in research and theorizing in psychology and education, computer science, management, and communication have led to a preference for a "systems" model for describing and managing instructional development (ID). The use of this scheme in education and training evolved from the widespread success of similar approaches for designing weapons and other systems during and since the second World War, such as putting a man in space (Carter, 1973). As it is used for ID there are four main phases or stages which represent the sequence of activities involved. The initial Analysis phase determines the need for ID and identifies what curricula are to be developed. In the Design phase, the curriculum content is analyzed, terminal and enabling objectives are specified in detail, testing procedures are developed, student entering capabilities are determined, and blueprints for the instruction are made. The actual preparation of materials for instructing and of a management system takes place during the Development phase. Finally, during the Implementation phase, instructors are trained and the materials are tested, revised when necessary, and used when satisfactory. Recent publications describe these functions in detail (e.g., Dick & Carey, 1978; Gagné & Briggs, 1974).[3] The military services have adopted a form of the procedures developed by R. K. Branson and his colleagues (1975) at Florida State University and called the Interservice Procedures for Instructional Systems Design.

Complexity of curriculum planning and instruction development. In a global sense, the systems approach to curriculum design and instructional

development probably describes what has to take place anytime traditional instruction is developed.[4] What the approach adds to less formalized approaches is descriptive detail and the possibility of better quality. The more precise the definition of what students are to learn, and how their achievement will be assessed, the better able one is to structure and sequence instructional materials, and the more effective and efficient the students' learning is likely to be. The price paid for this precision is a tremendous increase in the difficulty of keeping track of all the details.

A year or so ago at our Center, we began an attempt to outline the details of the ID process. This effort resulted in a flowchart which depicts the tasks to be performed, the management and instructional decisions to be made, who might do those things, and the flow of concrete products/materials and information being passed around for various purposes within and outside the ID effort. Figure 1 shows part of that flowchart. As complicated as it may seem, it is a super-

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Insert Figure 1 about here

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ficial description of the Design phase of the process. Hidden in this picture are the intricacies of the procedures and the demands for record keeping involved with specification and classification of objectives, generation of test items and achievement tests, the choice of instructional strategies, etc. There are two broad classes of information records to be kept and organized--those concerned with managing the

development program as a whole and those concerned with preparation of instruction. For example, managers have to be concerned with assigning people to tasks, how much time they spend, ordering special equipment as it becomes required, arranging for printing materials or films, informing school administration of progress, arranging for classroom construction, instructor training, and trial implementations, etc. On the instruction side, details of decisions about instructional strategies and their relation to objectives, test items, and presentation schemes present only part of a formidable record keeping problem.

Let me illustrate one aspect of this latter problem with an example discussed recently by Popham (1978) in his book on criterion-referenced test development. An important part of criterion-referenced testing (CRT) is the requirement to generate a test item description scheme from which sets of items can be generated which are homogeneous; i.e., where students ought to respond to each item in an identical fashion. When tasks are complex, test item specification becomes difficult and there is a potential diversity of items that can be generated legitimately from the test item specification. For example, if the intent is to test a student's proficiency in multiplying pairs of two digit numbers, item sets could be drawn which differ in difficulty. Suppose in one set all pairs had zero in the units digit, e.g., 20 x 10, 40 x 30, etc. Although it is unlikely that achievement tests would be used which differ as obviously as that, the point is that with complex tasks, it becomes increasingly difficult to generate test item specifications which will generate truly homogeneous test items. The reason

for this may be that the task has not been analyzed sufficiently, or that some students misunderstand aspects of the problem (cf. Heller & Pellegrino, 1979).[5] Popham suggests that in spite of this possibility we must compromise. His implication is that test specification can be carried no further because to do so would result in more and more subcategory specifications and this becomes unmanageable. However, for instructional purposes it may be necessary to be able to diagnose defects in students' test performance so that remedial action can be undertaken (e.g., Brown & Burton, 1978). Therefore, some means must be found for managing the information resulting from more complete analysis of student performance so that item specification suitable for diagnostic testing can be accomplished.

Maintaining quality in the ID process and products. Although the belief that a systematized approach to ID is preferable to haphazard alternatives, there is widespread uncertainty as to whether the details of the process are sufficiently well enough understood to be used reliably by different individuals. This is sometimes attributed to a lack of specificity of the procedures and suggests the need for finding individuals of high levels of expertise to maintain the quality of ID (e.g., Brock, 1977; Montemerlo & Tennyson, 1976). Without the specificity, it is suggested that so much is left to the designer's/developer's imagination that instruction developed will vary widely in quality and be mostly poor. As one example, Bormuth (1970) suggests that biases exist in test item writing practices so that even when objectives are well specified, there can be substantial differences in items written

by different people. Studies testing this hypothesis find that given the same objectives different writers confound or confuse the intent of the instruction or produce flawed items (e.g., Roid & Haladyna, 1978). For this subtask of the ID process, this has led some workers to attempt to improve item specification procedures and provide better rules for writing items which remove some of the subjectivity from the process (e.g., Hively, 1968, 1974). Further development is necessary.

Our study of the methods used for ID by the Armed Services (Branson, et. al., 1975) reveals that the lack of precise operational procedures exemplified in writing test items is a problem common to other tasks as well. The tasks necessary for accomplishing the various ID phases are listed, but not well described. What seems necessary is to better analyze the tasks required of the instructional designer/developer and to develop means for assisting in the process. One means we have taken to assist the process takes the form of diagnostic evaluation and reform of the products and processes of ID, which we refer to as quality control (e.g., Montague, 1978). Dr. Wulfeck will be describing some of this work in this symposium. A number of quality control procedures and other aids need to be developed to assist in the maintaining or enhancing the effectiveness and increasing the efficiency of tasks in ID.

Cost and efficiency of instructional development. The ID process as described in Figure 1 and utilized in military training development combines professionals and subject matter specialists into development teams. The formalization of the organization and the process makes the

difficulty and complexity painfully apparent along with the magnitude of the resource requirements involved. An advantage is that detailed attention can be paid to ID costs which heretofore have been hidden in other administrative or teaching budgets. This latter point is an important one. In a recent review aimed specifically at evaluating the cost-effectiveness of numerous innovative instructional implementations in which materials were developed systematically for computer-based delivery management, no basis was found for comparing costs with more traditional development and delivery methods. Cost-effectiveness judgements were not possible (Orlansky & String, 1978). Now, given the adoption of the ID model, it is possible to establish cost baselines and work toward efficiency by adjusting the system.

The military, by adopting ID procedures and different organizations for managing the process, provides an interesting and perhaps unique opportunity for refining the procedures and evaluating organizational efficiency. For example, the Navy established a centralized management system for ID and operationalized this idea in what are called Instructional Program Development Centers. These Centers, located in different parts of the country, are manned by civilian ID personnel who are joined by military subject-matter experts for curriculum development. The other services utilize more distributed management schemes. However, in all cases detailed recording is made of the various manhour costs, material and any contractual support used in the various phases of the ID process and in administration.

The cost is currently high. A recent report (Chief of Naval Education and Training Support, 1979)[5] summarized the manhours expended in producing and implementing a course under this management scheme. Roughly 7000 hours of time for military and 78,000 hours of civilian personnel time were consumed in producing about 200 hours of instruction. Although this was the initial course produced by this organization, courses currently under development show about the same rate of time consumption. The formal organization and management of ID allows the study of its effectiveness and raises concern for efficiency. Systematic examination of how well the system works can produce efficiency gains through changes brought about by introducing new but well tested procedures. Many of these may be computer based. One example of attempts to gain efficiency via computer-based aids will be presented by Dr. Carpenter-Huffman. It is a development at RAND that makes planning instruction simpler by simulation of various resource allocation schemes.

The visibility of the high costs associated with formal ID schemes is of concern to those concerned with the general acceptance of this technology. For example, Gustafson (1977) is concerned that school systems cannot or will not afford million dollar course development efforts and might ignore it altogether. It does not fit into the ways in which school systems do business. The inference is that ID methodology must be made available without the formal and costly external organization, so that it can be used by people within school systems for curriculum changes. It seems reasonable that computer-based aids may play an important role in transferring ID technology and managing developments without special formal organizations.

Computer-Based Aids to Design and Development

There is widespread confidence that adoption of a systems approach has been an important advance in the evolution of techniques aimed at providing better quality instruction. It is apparent from the previous discussion that the process in itself is complex and presents a variety of information management and other problems. The fact that some of the procedures are sketchy and provide only general guidance for tasks such as test and instruction design suggest that procedural and training aids would be useful for detecting difficulties in doing design tasks and for detecting differences among designers. Can means be found for improving the guidance, monitoring designer's performance, or providing systematic training for ID team members? Computer-based systems can fill many of these roles. For the purposes of the symposium, consider that there are four broad classifications of computer-based aids serving various ID and/or administrative functions:

Data-base management aids

Instructional design decision aids

Material production aids

Personnel training aids

Although these classes may not be mutually exclusive, they provide a basis for illustrating the use of computer systems in ID, and they provide a frame of reference for categorizing the work presented by the other symposium participants.

Data-base management aids. The use of computer systems to help store and retrieve large quantities of information is becoming

widespread for various scientific and industrial purposes. For example, seismic data from all over the world are collected and stored in real time in one system. Data are stored in terms of location, time of recording and measuring instrument. Certain processing of the data is undertaken for detection of seismic events and the processed information is stored as well as the raw data. A user can select arbitrary subsets of the information for printing or further processing from remote terminals or systems (see, Marill in Seidel & Rubin, 1977). Various similar applications in ID are possible. Administrative management of the instructional program development organization would be straightforward and could improve coordination of activities and perhaps reduce administrative costs. Data regarding personnel assignments to ID tasks, time spent, and accomplishments could be stored in a system and readily retrieved for a variety of purposes. Data could be input from designers about their decisions regarding instructional devices which cue administrative scheduling action. Such aids serve the purpose of eliminating some of the confusion and time delays resulting from the tremendous complexity and the amount of paperwork necessary in large ID projects. A simple example of this kind of use was undertaken by our Center to aid the Navy Instructional Program Development Center, San Diego. In order to be able to report the expenditure of personnel time in the various ID phases without the significant delay inherent in the then existing system, a simple program was prepared on our PDP-11. At a remote terminal, a secretary enters each ID team members time data broken down into various categories. This

information can be retrieved in various forms appropriate for reporting or other administrative purposes.

In a similar fashion, data-base management can directly aid instructional design. Files of objectives, test-item specifications, and collections of test items, as well as segments of instruction or instruction specifications would provide substantial reduction in the paper work. It would also allow comparison among objectives in order to coordinate the selection of appropriate conditions of instruction. Data-base management is also important in providing organized data files for purposes of evaluation. Student tryout information can easily be collated and assist in test validation and determining the adequacy of instructional materials.

Instructional design decision aids. The purpose of aids falling into this classification is to assist designers at critical points in the ID process. A variety of such aids is possible. Simple ones might simply guide and monitor a designer step by step through the process. Others, somewhat more complicated, might provide guidance as to how to go about accomplishing each task. Still others could provide detailed assistance by accessing stored data bases, summarizing information, and assisting in making choices among alternatives. For some years, attention has been given to the use of computer aids in generating tests. Although they might not have been the first, over ten years ago Hively, Patterson, & Page (1968) attempted to define test-item specifications in a form that would allow computer generation. Recently, Gagné (1976)

described a similar approach. The attention to aiding test construction is understandable. It provides the main basis for evaluating instructional adequacy as well as student accomplishment, and is often difficult to manage.

Instructional designers make many choices about the ways in which instruction will be undertaken, and the media which will be used for presentation. Computer-based systems can assist in these choices. Part of Dr. O'Neal's presentation will be concerned with an aid which summarizes information about objectives and related learning condition requirements in order to help optimize the best overall instructional scheme. Dr. Nawrocki will also describe some developments at the Army Research Institute that fall into this category.

Another kind of useful aid for ID is one that assists in quality assurance. For example, test items, objectives, and instruction must be congruent or consistent. Testing condition constraints often allow instructional designers to develop tests which test something other than that competency specified in the objective. Dr. Wulfeck will discuss a system to be used for this sort of quality control. An exemplary system which is an elaborate aid for ID and management decisions will be described by Dr. Carpenter-Huffman. Using a simulation of the ways in which resources are arranged and used in instruction, a designer can test planned implementations to test for the best among alternative arrangements. Simulations such as this could be very important for increasing the efficiency of ID.

Material production aids. In this classification of computer-based aids fall those used for facilitating authors' writing, editing, and producing materials. The intent of these aids is to make the writing and production of the materials simpler and faster, thereby reducing complexity for managing the work and reducing costs. Many systems having similar functions already exist and have increasingly widespread use in universities, business, and industry. Although there are differences in elaborateness and perhaps in ease of use, for our purposes they all operate roughly in the same way.

The author sits at a terminal and logs onto a computer and is then connected to a materials editing and production system. S/he operates through an executive program which provides access to various functions. Given a simple command, the executive allows the author to type in text or other symbolic information on the keyboard and stores it in a special dataset or file. By using other simple commands, the author can then examine the contents of the file, delete, change, or insert new text at any point. The text stays in the file until the author completes the material. Systems capable of generating graphics are more expensive and elaborate and are, therefore, rarer. But they can be organized to operate in a similar mode. When the author has completed the text, a command to the executive provides access to a text processor which takes the rough draft text (in which the author embedded instructions as to format) and types or prints it in finished form. Various kinds of output devices can be used including high-speed typewriters and photo-typesetting systems.

A system having some of these characteristics will be described by Dr. Braby. The system is intended for use by authors who are subject-matter specialists to prepare and produce programmed instruction materials. Time required for authoring materials is reduced, and more importantly, the requirement for authoring expertise is reduced. This system does not allow the flexibility inherent in text editing systems described above; rather, the executive program requests specific information in a particular format from the author, and then arranges it in a format appropriate for different parts of the programmed text. What is important in this approach is the fact that the program acts as the instructional designer.

Personnel training aids. The reason for including this classification is apparent in the difficulty of doing ID tasks and the lack of experienced personnel to staff the ID teams. Personnel turnover adds to the problem. To some extent, some of the aids described earlier under instructional design decision category may do double duty and serve to train personnel. However, more direct attention needs to be given to means for teaching or maintaining the skills needed by ID personnel. Courses could be developed to cover everything from general orientation to the organization and its workings, to instruction on methods of writing materials (or using text editors). In order to provide the capability of adjusting to the needs of different individuals, to provide an opportunity to monitor their performance, and to allow course expansion as necessary, a computer-based system seems preferable. Some of the developments presented by Dr. O'Neal and Dr. Nawrocki are germane to this issue.

Intelligent Aids to Instructional Design and Development

As was mentioned earlier, Dr. Braby's work suggests that computers can serve as ID experts in order to assist subject-matter specialists in preparing instruction. The idea is to have the specialist sit down at a terminal and interact with a program that constructs a representation of the subject matter which is used for developing the instruction. This intelligent ID aid is similar to Artificial Intelligence aids to instruction.

Over the past several years, research groups at Bolt, Beranek, and Newman, Stanford, and the Massachusetts Institute of Technology among others, have been experimenting on new conceptions of a learning environment (see Session 4 in Seidel & Rubin, 1977). In the computer is a model or representation of a subject matter and programs which permit interaction with a student, and which directs the construction of a representation of what the student knows about the topic. In some cases, the computer acts as a tutor, patiently asking questions determined by the program's understanding of what the student does not know. Such systems provide a reactive learning environment that allows the student to discover the domain by actively probing the information in the data base and being guided heuristically by the tutoring or coaching programs. Thus, the system contains problem solving, question answering, and tutoring expertise, in addition to the subject-matter knowledge. For several reasons, it seems reasonable to call for the development of a similar system for ID.

Perhaps foremost among the reasons concerns the costs of current ways of doing ID, and the availability of skilled personnel along with the variability in their competence. Of course, these same reasons motivated the development of the other aids discussed in this symposium. However, there is a more subtle, and perhaps more important reason. By adopting an ID model and organizing to develop instructional materials using the model, it is assumed that the procedures are well understood and that different ID personnel will develop equivalent materials. As was mentioned earlier, there is doubt about the validity of this assumption. In test-items writing, which is so fundamental to all instructional development, considerable variability is found among item writers. In addition, the idea that ID can be done well only by highly experienced and knowledgeable persons is mentioned often, and serves as the basis for arguments that completely proceduralized systems for developing instruction will not work very well (e.g., Brock, 1977; Montemerlo & Tennyson, 1976). The suggestion is that we do not yet understand how to go about analyzing tasks and structuring instruction very well. The simpler aids aimed at reducing confusion and paperwork or making sure that the ID personnel adhere to the steps laid out in the model may not provide very much improvement. By assuming that the steps are simple and known, they do not provide us with any greater understanding and will permit considerable variability among developers. The point is that if attempts are made to understand the processes of instruction and how

to develop instruction in sufficient detail to allow the development of intelligent computer programs, the gain in understanding will be of significant benefit to ID. Therefore, developments attempting to construct intelligent computer-based aids for designing instruction directly increase the understanding of the process and thereby directly increase our ability to apply this knowledge (cf. Greeno, 1978).

The computer-based aids discussed in this symposium provide a foundation for more advanced systems in the future. Active efforts need to begin to evolve more intelligent aids from these rudiments.

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Footnotes

[1]The assertions herein are those of the author and are not to be construed as official or reflecting the views of the Navy Department. This paper was presented at the American Educational Research Association 1979 Annual Meeting, April 8-12, San Francisco, California, Section 6.04 Automated Aids to Instructional Design and Development.

[2]The author is on assignment with the Learning Research and Development Center, University of Pittsburgh, Pittsburgh, PA 15260, until June 1979.

[3]I have excluded evaluation as a separate function because much formative and some summative evaluation is enmeshed in the whole process of ID (cf. Tennyson, 1976).

[4]Certain developments in teaching relatively ambiguous metacognitive skills like thinking, or approaches to problems, exemplified by discussions by Minsky, and by Papert (in Seidel & Rubin, 1977) do not fit into the systems model.

[5]Heller, J., & Pellegrino, J. W. Individual differences in verbal analogy solution skills. Paper presented at the AERA meeting, 1979.

[6]Chief of Naval Education and Training Support memorandum: Instructional program development cost report, January 25, 1979.